National Aeronautics and Space Administration

Asteroid Redirect Mission
Building Human Space Flight Exploration Capabilities

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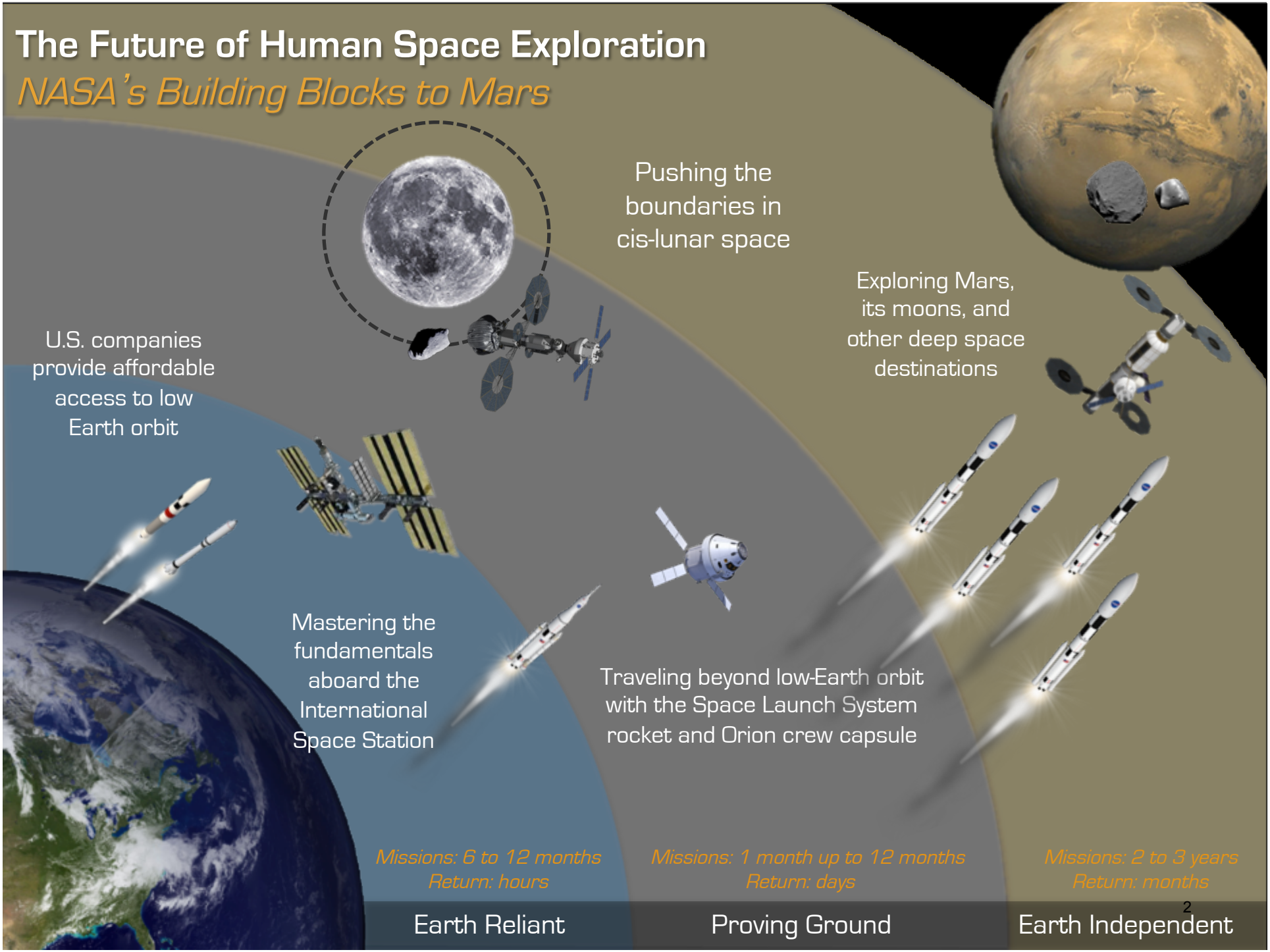
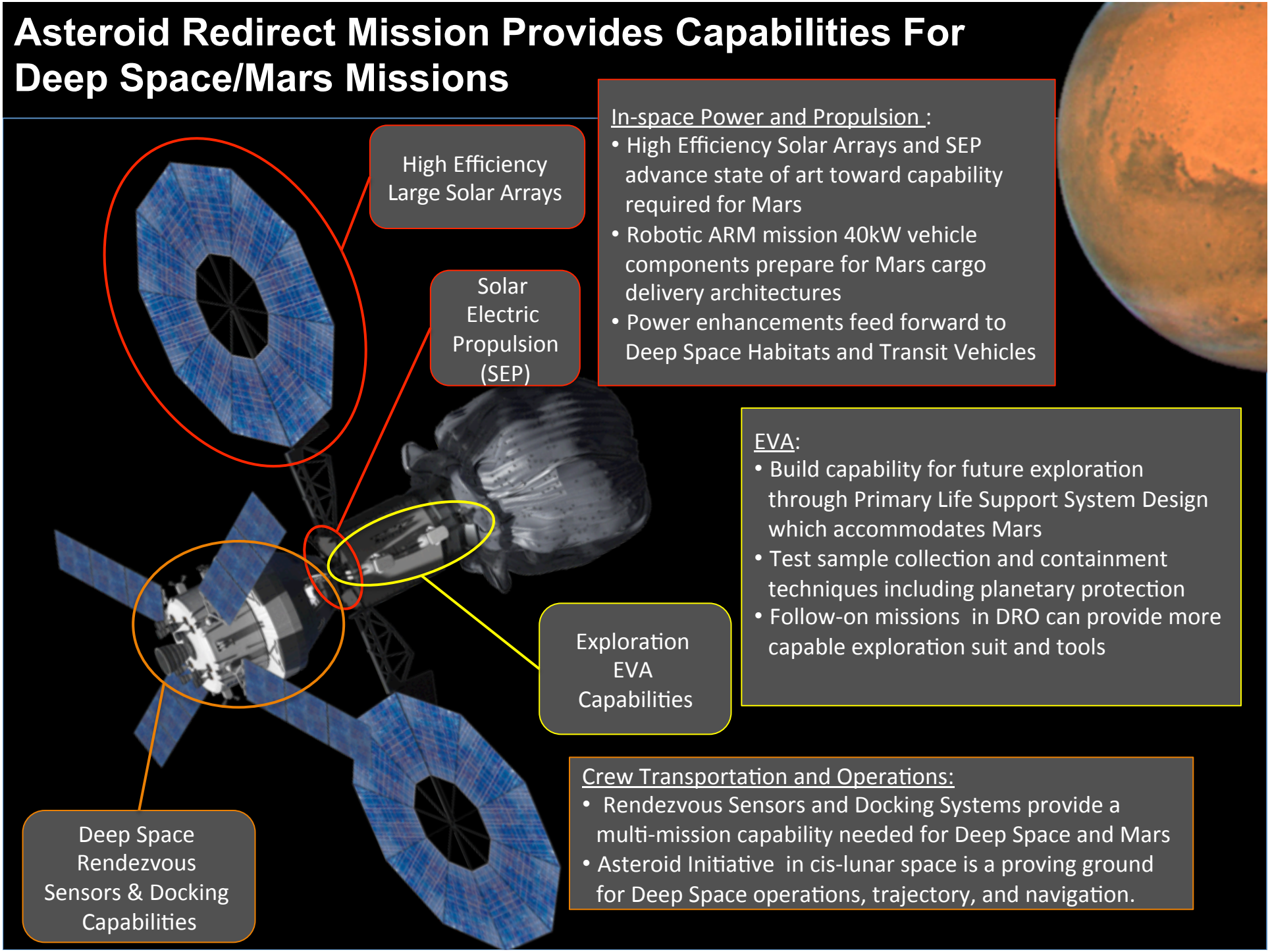
The Future of Human Space Exploration

NASA's Building Blocks to Mars



Asteroid Redirect Mission Provides Capabilities For Deep Space/Mars Missions



<u>In-space Power and Propulsion</u> :

- High Efficiency Solar Arrays and SEP advance state of art toward capability required for Mars
- Robotic ARM mission 40kW vehicle components prepare for Mars cargo delivery architectures
- Power enhancements feed forward to Deep Space Habitats and Transit Vehicles

<u>EVA</u>:

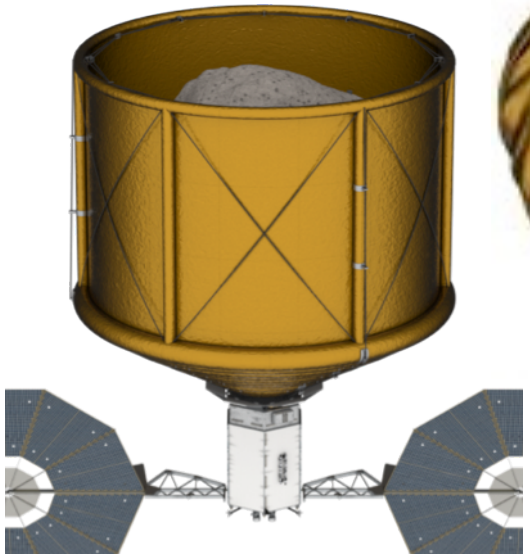
- Build capability for future exploration through Primary Life Support System Design which accommodates Mars
- Test sample collection and containment techniques including planetary protection
- Follow-on missions in DRO can provide more capable exploration suit and tools

<u>Crew Transportation and Operations:</u>

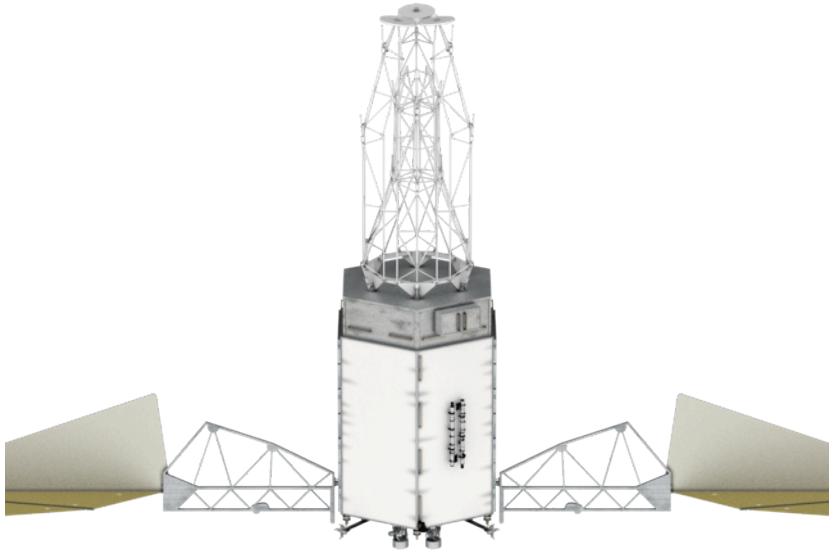
- Rendezvous Sensors and Docking Systems provide a multi-mission capability needed for Deep Space and Mars
- Asteroid Initiative in cis-lunar space is a proving ground for Deep Space operations, trajectory, and navigation.

Robotic Mission Concept Options

Small Asteroid Capture: Option A



Larger Asteroid Boulder Capture: Option B

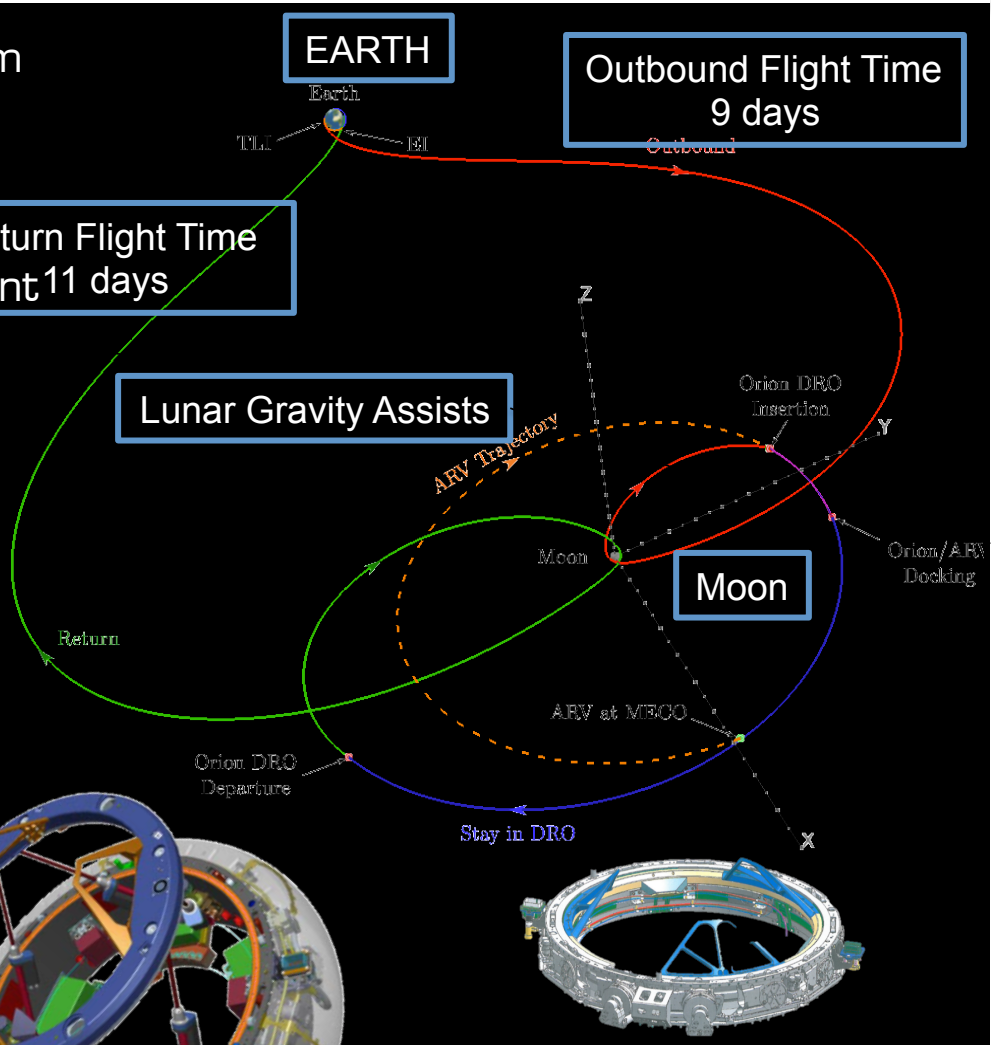


Asteroid Redirect Crewed Mission

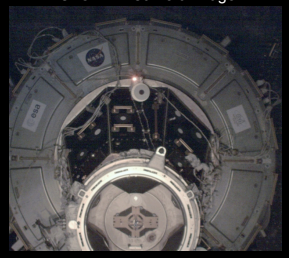
Leveraging Existing Investments:

Deep Space Trajectory, Rendezvous, Docking

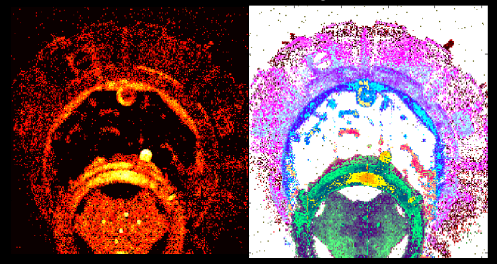
- Rendezvous/prox-ops sensors derived from Space Shuttle Detailed Tests
- Trajectory launch constraints, rendezvous techniques, navigation enable Mars
- Lunar gravity assist is learning environment for Mars cargo pre-deployment or human Venus fly-by
- Docking System is Derived from ISS International Docking System

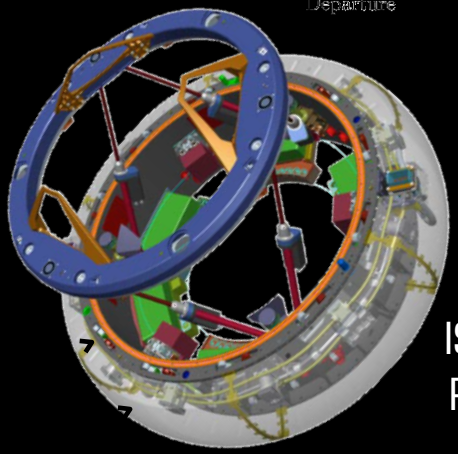


STORRM Camera Image



STORRM LIDAR Images





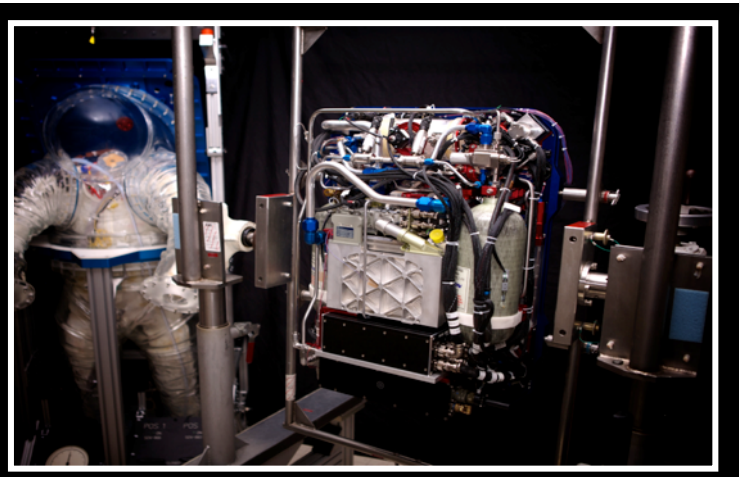
ISS Derived Orion Active and Passive Docking Mechanism

Leveraging Existing Investments:

EVA Suit and Primary Life Support System (PLSS)

- Exploration PLSS- capable with small modifications of ISS EVA demonstration, Exploration Suit, or Modified Advanced Crew Escape Suit (MACES) via an architecture that is Mars capable
  - Initial PLSS prototype completed in FY13
  - WSTF Variable Oxygen Regulator flammability testing
  - Integrated metabolic and functional testing in FY14
- Exploration Suit - Architecture support mission requirements, represented in a Mars mission, that is applicable to any surface, and adaptable for micro-gravity

Completed PLSS 2.0 Test Article



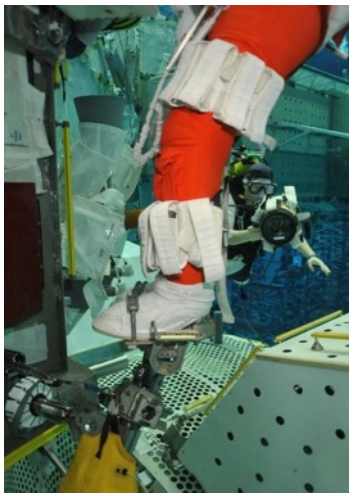
MACES with PLSS and EVA Suit Kit

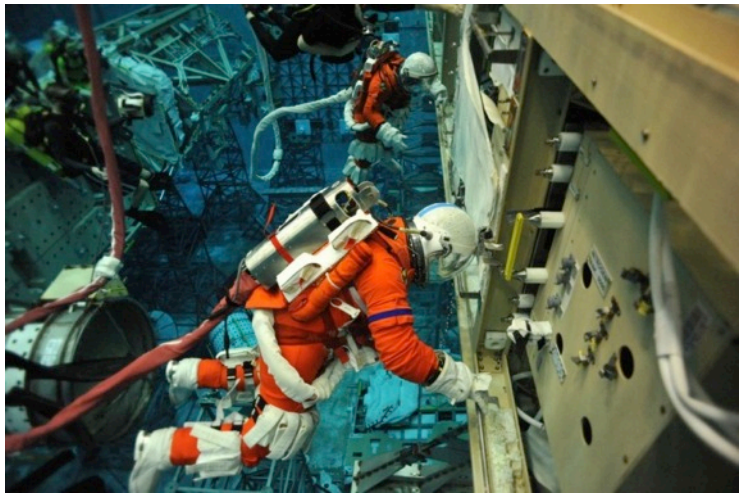
Z-2 Exploration Suit

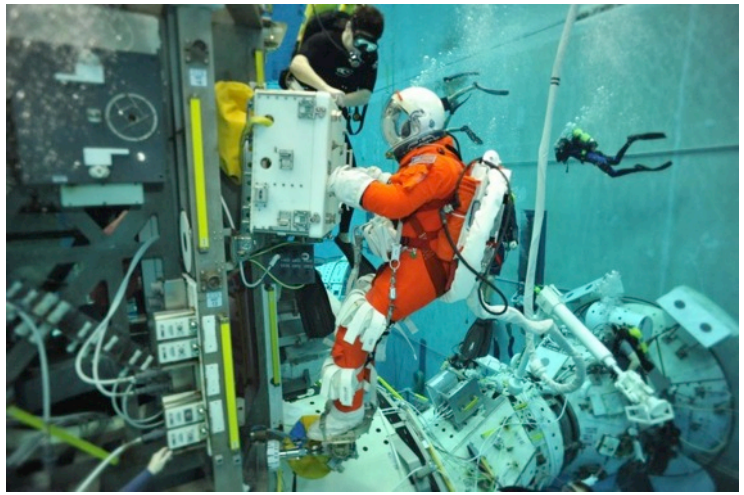
Modified ACES EVA Testing in NBL

- February 2014 testing focused on first portion of spacewalk (egress, translation, worksite prep):
  - 2 Crew Capability
  - Enhanced Suits with arm bearing and positioning
  - EMU Boots
  - Portable Foot Restraint

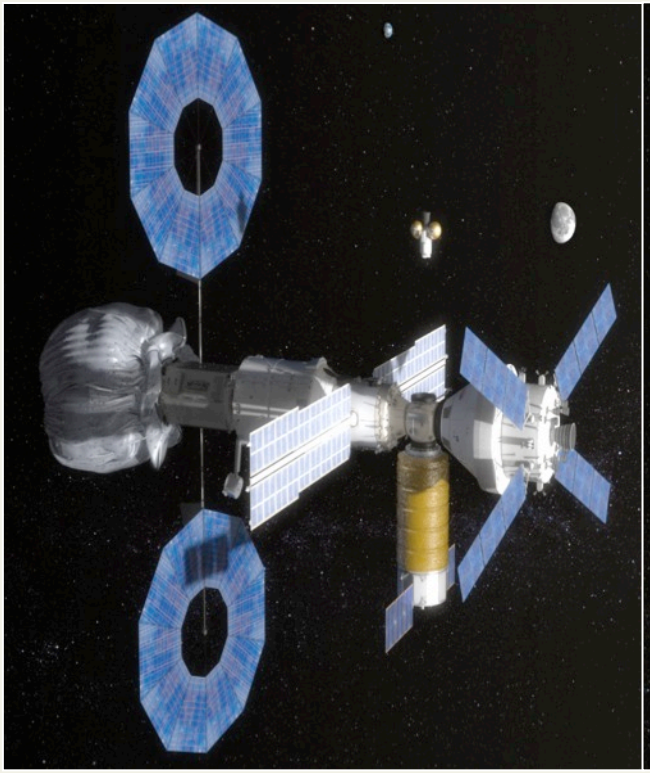
- April test series will emphasize sample capture and worksite stability



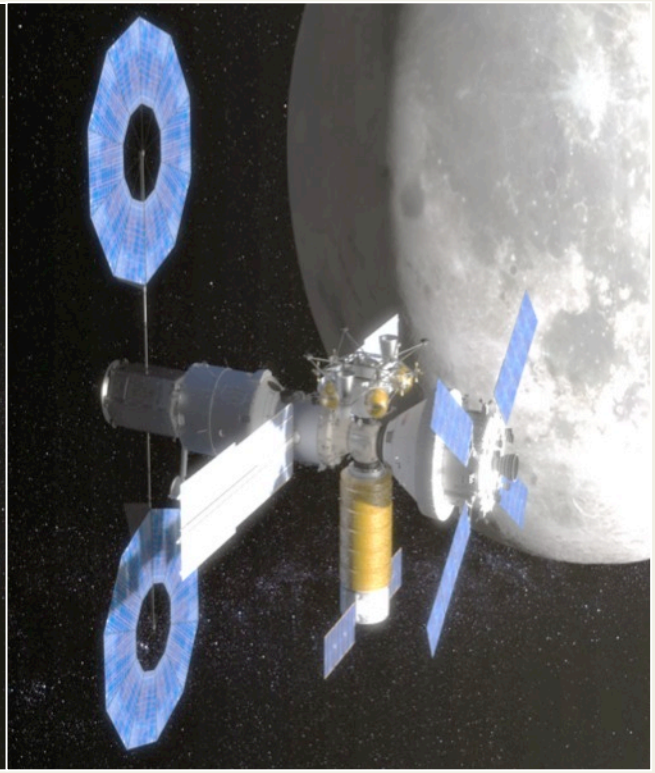




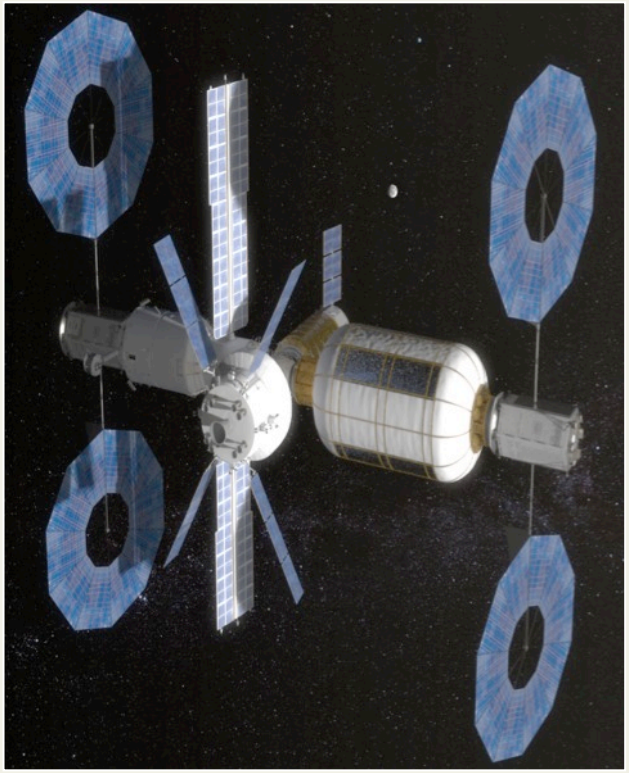
Asteroid Redirect Mission Builds upon Orion/SLS to enable Global Exploration Roadmap



Asteroid Exploitation Missions



Lunar Vicinity Missions



Deep Space Missions

Human Exploration Pathways

Mastering the Fundamentals

- Extended Habitation Capability (ISS)
  - High Reliability Life Support
- Deep-space Transportation (SLS and Orion)
- Exploration EVA
- Automated Rendezvous & Docking
- Docking System

Pushing the Boundaries

- Deep Space Operations
  - Deep Space Trajectories
  - Deep Space Radiation Environment
  - Integrated Human/Robotic Vehicle
- Advanced In-Space Propulsion (SEP)
  - Moving Large Objects
- Exploration of Solar System Bodies

On to Mars

Land on Mars

Towards Earth Independent
Crewed Orbit of Mars or Phobos/Deimos

To Moon And Beyond
(International and/or Industry Partners)

To Mars

"Bringing the Moon Within Economic Sphere of Earth"

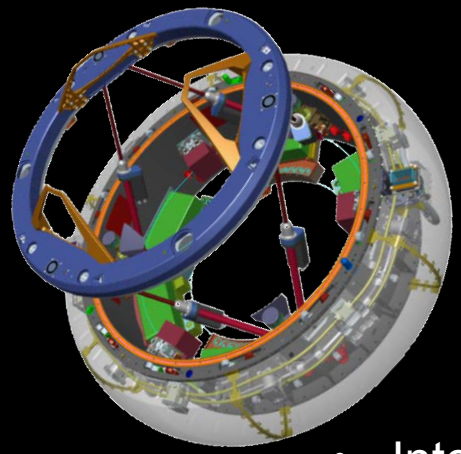
ISS and ARM Provides First Steps to Mars

	Mission / Sequence	Current ISS Mission	Asteroid Redirect Mission	Long Stay In Deep Space	Mars Orbit	Mars Surface, Short Stay	Mars Surface, Long Stay
Mars Destination Capabilities	In Situ Resource Utilization & Surface Power						X
	Surface Habitat						X
	Entry Descent Landing, Human Lander					X	X
	Advanced Cryogenic Upper Stage				X	X	X
Initial Exploration Capabilities	Deep Space Habitat			X	X	X	X
	Exploration EVA		X	X	X	X	X
	Solar Electric Propulsion for Cargo		X	X	X	X	X
	Deep Space Guidance Navigation and Control/Automated Rendezvous		X	X	X	X	X
	Crew Operations Beyond LEO – High Speed Entry (Orion)		X	X	X	X	X
	Heavy Lift Beyond LEO (SLS)		X	X	X	X	X
ISS Derived Capabilities	Deep Space Habitat	* →		X	X	X	X
	High Reliability Life Support	* →		X	X	X	X
	Autonomous Assembly	* →		X	X	X	X

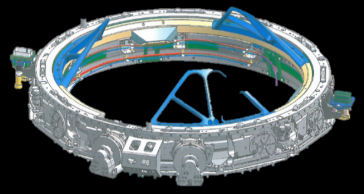
Back-Up

Docking System

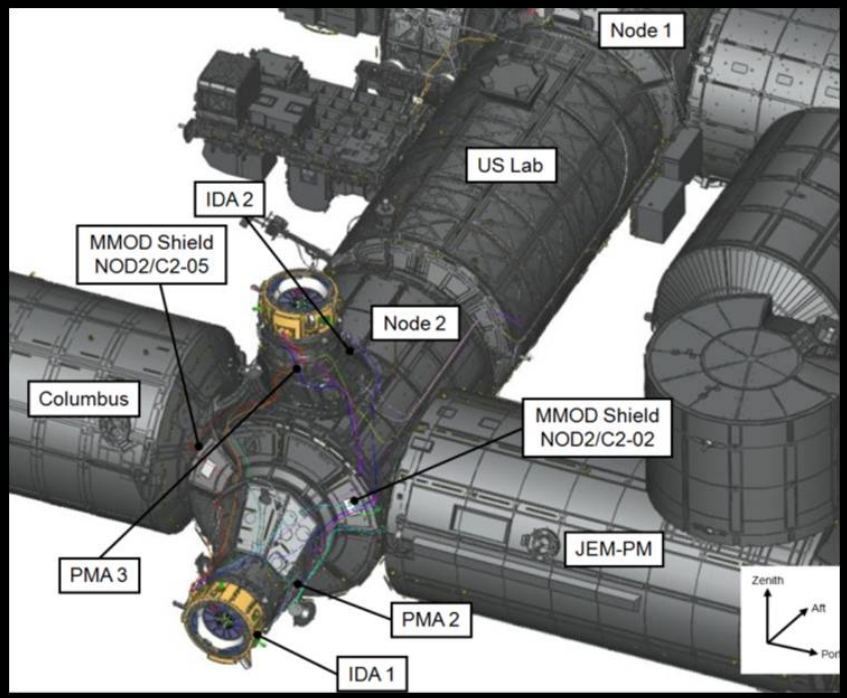
- **Docking System for Orion and Robotic Spacecraft leverages development of International Docking System Block 1**
- **All Mars/Deep Space Architectures will require some form of autonomous docking**



Orion Active Docking Mechanism



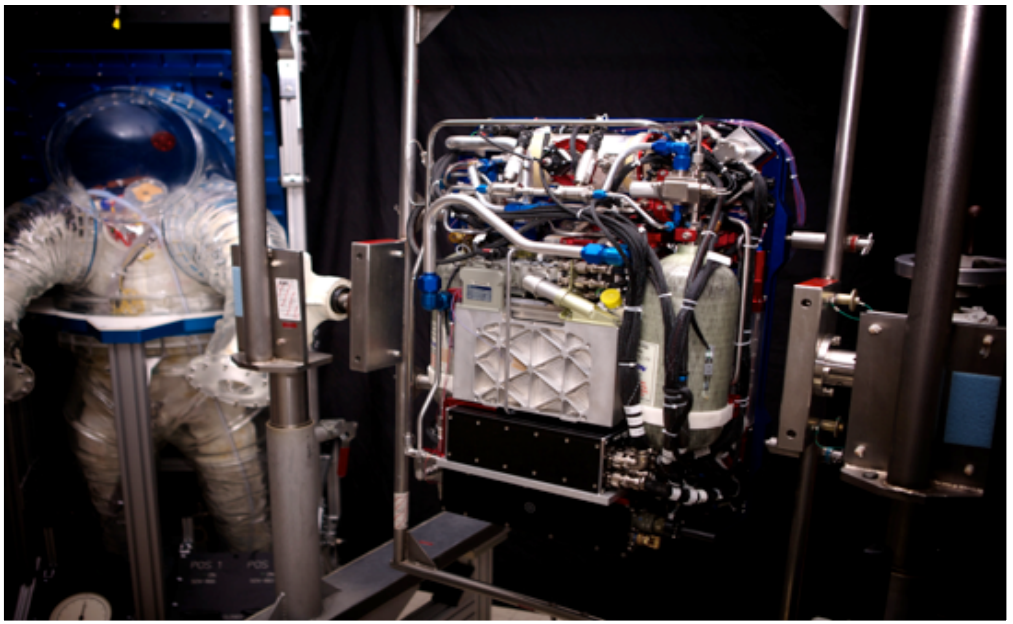
Robotic Spacecraft Passive Docking Mechanism



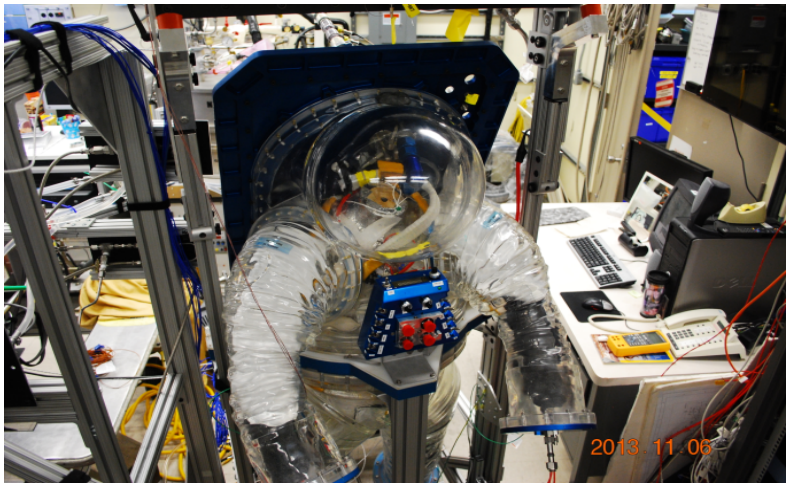
- International Docking Adapter will create a docking port on ISS to provide power and data utility connections to visiting vehicles
- Beginning FY14 study with ISS Program to evaluate Block I to Block II:
  - Voltage and avionics
  - Deep space environment
  - Mass reduction opportunities
  - Overall system design efficiency

EVA Suit and Primary Life Support System (PLSS)

- **Exploration PLSS- capable with small modifications of ISS EMU, Exploration Suit, or M-CES with architecture that is Mars capable**
  - PLSS 2.0 prototype completed in FY13
  - Variable Oxygen Regulator flammability testing completed at White Sands Test Facility
  - FY14 work includes integrated metabolic and functional testing and fabrication of a PLSS/MACES integration kit will be completed in FY14



MACES with PLSS and EVA Suit Kit



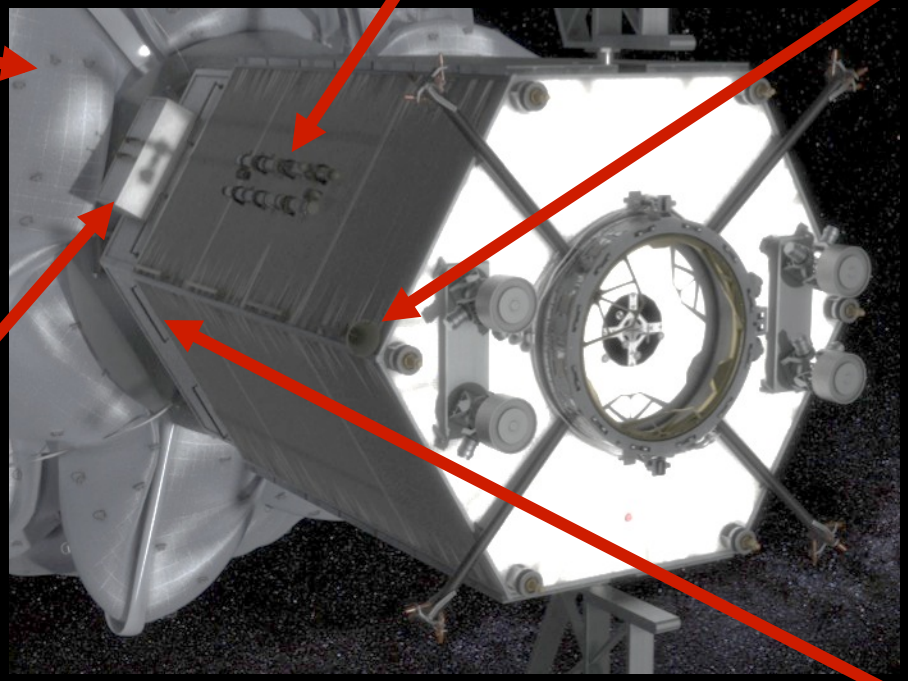
Liquid Cooling and Ventilation Garment Heated Manikin in Space Suit Simulator

Variable Oxygen Regulator Testing at WSTF

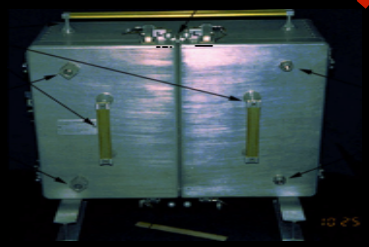
EVA Accommodations for Crewed Mission

EVA Tether Points
- Hand-over-hand translation
- Temporary restraint of tools
- Management of loose fabric folds

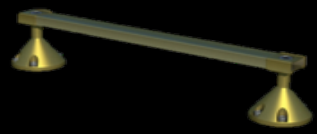
EVA Translation Booms
- Translation Booms for Asteroid EVA



EVA Translation Attach Hardware
- Circumference of Mission Module at base of Capture System and ARRV-Orion Interface

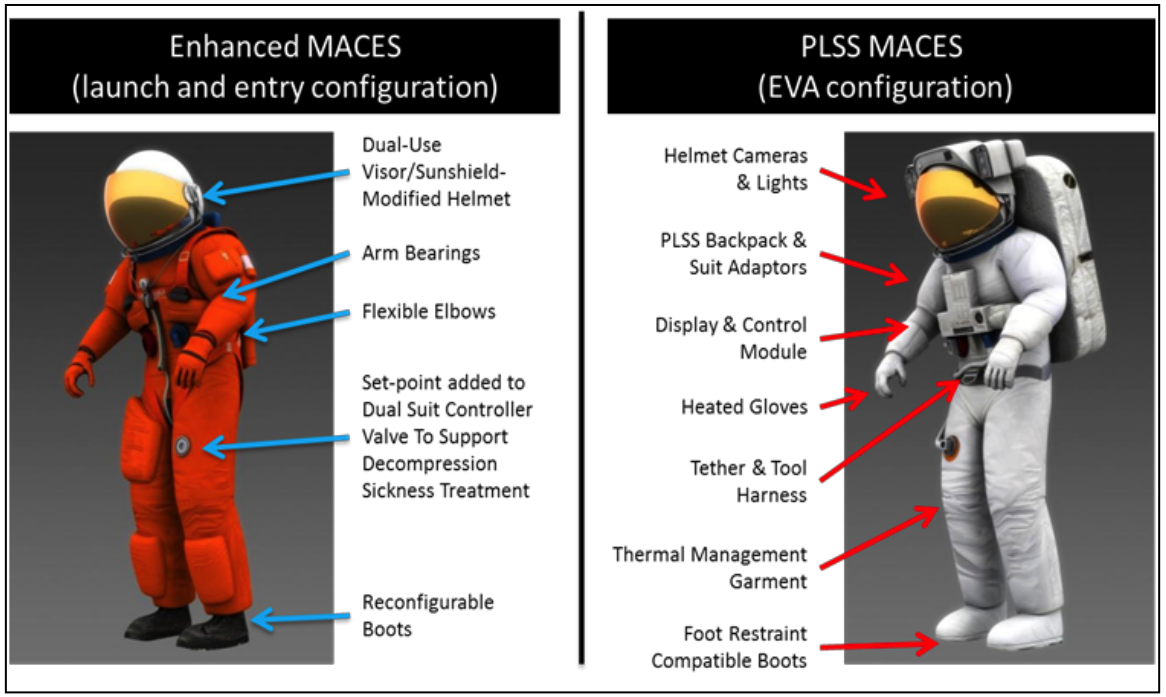


Pre-positioned EVA Tool Box
- Tool box to offset Orion mass (85kg tools)



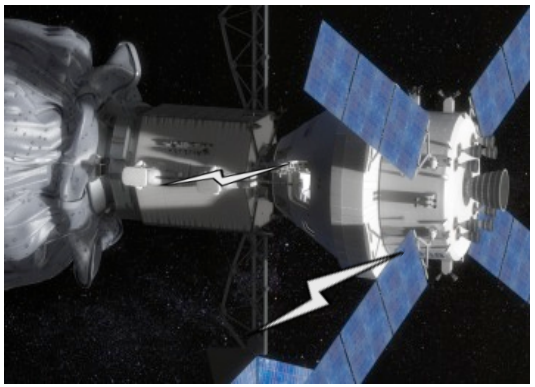
Hand Rails
- Translation path from aft end of ARRV to capture bag
- Ring of hand rails around ARRV near capture bag

Mission Kit Concept Enables Affordable Crewed Mission

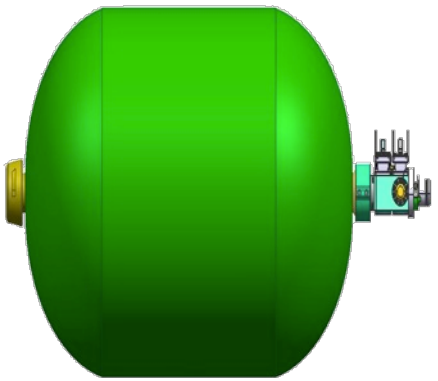


Tools & Translation Aids

Sample Container Kit



EVA Communications Kit



Repress Kit